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A review on the use of electric devices to modify animal behaviour and the impact on animal welfare

Opinion of the Panel on Animal health and welfare of the Norwegian Scientific Committee for Food and Environment

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Preparation of the opinion

The Norwegian Scientific Committee for Food and Environment (Vitenskapskomiteen for mat og miljø, VKM) appointed a project group to answer the request from the Norwegian Food Safety Authority. The project group consisted of two VKM members from the Panel on Animal Health and Welfare and a project leader from the VKM secretariat. Two external referees commented on and reviewed the manuscript. The VKM Panel on Animal Health and Welfare evaluated and approved the final opinion drafted by the project group.

Authors of the opinion

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Assessed and approved

The opinion has been assessed and approved by the VKM Panel on Animal Health and Welfare. Members of the panel are: Brit Hjeltnes (chair), Øivind Bergh, Knut Egil Bøe, Carlos Goncalo Afonso Rolhas Fernandes das Neves, Jacques Godfroid, Roar Gudding, Kristian Hoel, Cecilie Marie Mejdell, Stein Mortensen, and Espen Rimstad.

(Panel members in alphabetical order after chair of the panel)

Acknowledgment

VKM would like to thank Per Jensen, Linköping University, and Bjarne O. Braastad, Norwegian University of Life Sciences, for reviewing the opinion and providing constructive criticism. We would also like to thank Danielle Caroline Laursen for proofreading the final manuscript.

Competence of VKM experts

Persons working for VKM, either as appointed members of the Committee or as external experts, do this by virtue of their scientific expertise, not as representatives for their

employers or third party interests. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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Summary

Background

Animals have a strong aversion to electric shocks. Various types of electric equipment are used to modify the behaviour of animals by subjecting them to electric shocks. Outdoor electric fences are common among grazing animals in Norway and many other countries. The use of devices such as cow trainers in tie-stalls, electric goads in slaughter plants, and electric collars to teach dogs not to chase livestock, is regulated. The Norwegian Food Safety Authority (NFSA) is currently evaluating a virtual fence system, which delivers an electric shock if the animal crosses a defined boundary.

As electric shocks are experienced as unpleasant or even painful, animals will try to avoid it. The intension of delivering such an aversive stimulus is to teach it how to avoid getting shocked again. In other words, the animal must to be able to associate the aversion with its own behaviour in order to avoid it. Predictability and controllability are two import factors, which determine how well an animal copes with aversive events that may involve being exposed to shock. However, the animal may make associations between the electric shock and non-intentional events. The consequences for such erroneous assocations could be stressful, with serious implications for animal welfare. The same applies if the animal fails to learn how to avoid receiving an electric shock.

Terms of reference

In June 2017, NFSA asked the Norwegian Scientific Committee for Food and Environment (VKM) to summarise current knowledge on how animal welfare is affected by technologies or devices providing electric shocks used to modify animal behaviour. This includes, for example, outdoor electric fences, virtual fences, cow-trainers, electric goads and shock collars. In addition, NFSA also asked VKM to review current knowledge on automated equipment subjecting animals to alternative types of aversive stimuli, such as unpleasant odours.

Project group and evaluation of report

VKM appointed a project group comprising two members from the Panel on Animal Health and Welfare. Two external referees have reviewed the manuscript. The Panel on Animal Health and Welfare evaluated and approved the final report drafted by the project group.

Equipment using electrical stimuli

Electric fences are common in keeping domesticated animals within a pasture. Animals learn from experience to associate physical contact of the electric fence with shock, hence actively try to avoid it.

Virtual fences do not have visual, physical barriers. Instead, the pasture area is defined by boundaries on a computer. The animals wear a collar with electrodes, battery, and GPS attached to it. As an animal approaches the invisible boundary, a sound (or vibration) is emitted by the collar alerting it that an electric shock may follow if the animal continues to proceed towards the invisible boundary. Cattle and goats have been shown to be able to learn this virtual system. Wearing a collar for an extended period represents a welfare hazard, as skin irritasions or soreness may arise, especially if the equipment is heavy.

Remote controlled electric collars are used in aversion learning to prevent dogs from chasing sheep and cervids (legal) and in obedience training (illegal in Norway). This method requires a skilled handler who knows when to deliver the shock with regards to the dog's intention. In Norway, only certified handlers are allowed to use this method to train dogs. Nonetheless, unintended associations or unforeseen effects may arise. Side effects, such as the dog developing fear, passiveness or aggression can occur during obedience training.

Anti-barking collars produces a short electric stimulus when the dog barks, thus suppressing further vocalisations. The collar is automated and equipped on the dog for extended periods of time, without people being present. Negative effects on animal welfare may include increased anxiety.

Electric cow-trainers are used to keep the tie stall and animal clean. The device comprises an electrified rod mounted horizontally over the cow's back, producing an electric shock on physical contact. This occurs when the animal arches its back to urinate or defecate. The cow is supposed to learn to avoid the shock by stepping back before arching its back. There are contrasting reports on how cow-trainers affect animal welfare. Some studies have documented effects, such as increased risk of reduced fertility, higher prevalence of mastitis, hock lesions, more frequent injuries on joints and claws. Changes in behaviour, like abnormally slow or interrupted lying down movements, have also been reported. However, other studies report no effects or better claw health from using cow-trainers.

Electric goads are used to force animals to move in the desired direction in slaughter plants. The need for coercive means to drive animals depends largely on the design of raceways. From a welfare perspective, the use of electric goads is widely considered problematic.

Devices that produce electric shocks to immobilize animals are being used under certain situations in some countries, such as during surgery. Studies have indicated that immobilizing shocks are probably experienced by the animals as being more aversive or even painful than mechanical restraint.

Equipment using alternative aversive stimuli

Equipment that produces aversive stimuli other than electric shocks represents a less painful, but still unpleasant, alternative. For example, anti-barking collars that emit citronella scent or unpleasant sounds can be used to stop the dog from barking.

Conclusions

The conclusions in this opinion are based on reviewing the scientific literature.

Exposure to electric shocks is generally an aversive experience to animals and humans. The experience may vary from unpleasant to very painful, depending on the electric of the equipment in question, the circumstances, as well as individual factors.

There are few disadvantages with using electrical fences, since they are visible and the animal can keep its distance to it. This requires that fence design, space allowance and animal group composition is adequate. Successful containment of animals within virtual fences is dependent on that they have been sufficiently conditioned and the warning signal works as intended. Some species and/or individuals are quicker than others in learning the consequences of the warning signal emitted by the collar, and how to react to avoid a shock.

Automated electric devices that are attached on the animal for extended periods of time may represent a hazard to animal welfare. For example, skin irritations or malfunction causing, unintentional delivery of shock will have negative effect on welfare. Anti-barking collars with citronella are just as effective as electric collars in suppressing barking, although there are some indications that dogs may habituate to the aversiveness over time.

Cow-trainers in tie stalls are problematic from a welfare perspective. Although the electrified rod should be placed at least 5 cm over the cow's back, this may not always be the case in practice. The cow may receive unintentional shocks simply by stretching its body, and the lying down and getting up behaviour is affected.

Shock collars are often effective in learning dogs not to chase sheep, which is important for the welfare of the sheep. However, in general, the use of electric shocks has potentially significant welfare drawbacks, which is why their use is restricted to this type of avoidance learning in Norwegian legislation.

Data gaps and uncertainties

After reviewing the literature, we found several data gaps related to electric equipment being used to modify animal behaviour. Research seems to place more emphasis on the functionality of electric equipment than on the consequences for animal welfare. Scientific data on how many shocks that are needed until the animal learns to avoid these is largely lacking. Short- and long-term welfare consequences for animals that have learned a particular system, as well as those individuals that are either slow or incapable of learning, is scarce.

Key words: VKM, Norwegian Scientific Committee for Food and Environment, Norwegian Food Safety Authority, animal welfare, electric shock, aversiveness, pain, punishment, obedience training, fences, cow trainers, electric collars, electronic collars, electric fences, virtual fences

Sammendrag på norsk

Bakgrunn

Dyr viser sterk aversjon mot strømstøt, og det finnes ulike utstyr som modifiserer dyrs atferd ved hjelp av elektrisk strøm. Strømgjerder utendørs er vanlig brukt for beitedyr i både Norge og mange andre land. For utstyr som kutrener i båsfjøs, elektrisk drivstav i slakterier og strømførende halsbånd på hund for å lære dem til ikke å jage husdyr, er bruken regulert i forskrift. En type usynlig gjerde, der dyret får et strømstøt hvis det krysser en virtuell grense, er for tiden under vurdering av Mattilsynet med hensyn på dyrevelferd.

Siden elektriske støt er ubehagelige eller smertefulle for dyr, vil de forsøke å unngå det. Hensikten med å bruke strømstøt er i de fleste tilfeller å lære dyret hvordan det skal unngå å få flere støt. Dyret må altså forbinde ubehaget med sin egen atferd, og forstå hva det skal gjøre for å unngå nye strømstøt. Forutsigbarhet og kontrollerbarhet er to viktige faktorer som avgjør hvor godt dyr takler situasjoner der de kan utsettes for strømstøt. Det kan imidlertid skje at dyret assosierer strømstøtet med noe annet enn det som var intensjonen. Konsekvensene av slik feillæring kan være en stressbelastning med potensielt alvorlige konsekvenser for dyrevelferden. Det samme vil være tilfelle dersom dyret ikke evner å lære hvordan det skal unngå strømstøt.

Oppdrag

Mattilsynet ba i juni 2017 Vitenskapskomiteen for mat og miljø (VKM) om å oppsummere aktuell kunnskap om hvordan dyrevelferd påvirkes av teknologier eller utstyr som utsetter dyr for strømstøt for å endre atferd. Det kan for eksempel være strømgjerder, virtuelle gjerder, kutrener, elektrisk drivstav og strømførende halsbånd. I tillegg ble VKM bedt om å oppsummere aktuell kunnskap om automatisk virkende utstyr som utsetter dyr for andre typer av ubehagelig stimuli, som for eksempel ubehagelig lukt.

Arbeidsgruppe og evaluering av rapport

VKM nedsatte en arbeidsgruppe bestående av to medlemmer fra faggruppen for dyrehelse og dyrevelferd. To eksterne fagfeller har gått gjennom og kommentert manuskriptet. Faggruppen for dyrehelse og dyrevelferd evaluerte og godkjente den endelige rapporten fra arbeidsgruppen.

Utstyr som gir dyr strømstøt

Strømførende gjerder er en utbredt metode for å holde husdyr innenfor et beiteområde. Dyra lærer av erfaring at fysisk kontakt med strømgjerdet fører til støt, og unngår å utsette seg for nærkontakt med gjerdet.

Virtuelle gjerder har ingen synlige, fysiske barrierer. Beiteområdet defineres i stedet ved hjelp av streker tegnet på et kart på datamaskinen. Dyra bærer et halsbånd med elektroder, et batteri og GPS. Når et dyr nærmer seg den usynlige grensen, sender halsbåndet ut en lyd (eller vibrasjon) som øker i styrke og som varsler at dyret vil motta et strømstøt dersom det fortsetter å bevege seg mot den usynlige grensen. Det er blitt vist at storfe og geiter kan lære seg dette virtuelle systemet. Når dyr bærer halsbånd over tid, er det alltid en viss fare for hudirritasjon og eventuelt gnagsår, spesielt om utstyret er tungt.

Fjernstyrte elektriske halsbånd brukes ved aversjonslæring på hund for å unngå at de seinere jager sau og hjortevilt (lovlig bruk) og ved lydighetstrening (ulovlig i Norge). Metoden krever kyndige trenere som kan levere støtet på rett tidspunkt i forhold til hundens intensjoner, og det er krav om autorisasjon. Det er likevel fare for feilaktige assosiasjoner og uforutsette bieffekter, som at hunden likevel jager sau om den har et vanlig halsbånd på, og ved lydighetstrening kan bieffekter være frykt for eieren, passivitet eller aggresjon.

Elektriske bjeffehalsbånd avgir automatisk et støt dersom hunden bjeffer, og reduserer dermed bjeffing. Hunden har halsbåndet på over en lengre tidsperiode og uten at mennesker er til stede. Negative velferdseffekter kan være økt engstelse hos hunden.

Elektrisk kutrener brukes i båsfjøs for å holde båsen og dyret reint. Kutreneren er en strømførende metallbøyle/-stang som monteres horisontalt på tvers litt over kuas rygg og gir støt ved berøring. Dette skjer når kua krummer ryggen før hun urinerer eller tømmer tarmen. Meningen er at kua skal lære seg å unngå strømstøt ved å ta noen skritt bakover før urinering/defekasjon. Data om hvordan kutrener påvirker dyrevelferden, er motstridende. Noen studier rapporterer økt risiko for jurbetennelse, skader på spener og bein og redusert fertilitet, samt endringer i atferd, som unormalt langsomme eller avbrutte bevegelser for å legge seg. Andre studier har ikke funnet negative effekter eller rapporterer om bedre klauvhelse ved bruk av kutrener.

Elektriske drivstaver brukes som tvangsmiddel til å få dyr til å bevege seg i ønsket retning ved slakterier. Behovet for å tvinge dyr fremover ved hjelp av smerte avhenger i stor grad av design av drivganger og binger. Fra et dyrevelferdssynspunkt anses bruk av elektriske drivstaver som problematisk.

Utstyr som gir strømstøt for å immobilisere dyr brukes i spesielle tilfeller i enkelte land, for eksempel ved kirurgi. Studier tyder på at immobiliserende elektrisk stimulering sannsynligvis oppleves som ubehagelig eller smertefullt, og er mer aversivt enn mekanisk fengsling.

Utstyr med andre ubehagelige stimuli enn strømstøt

Det finnes automatisk virkende utstyr som avgir andre typer ubehagelig stimuli enn strømstøt. Det kan for eksempel være bjeffehalsbånd som utsondrer sitronlukt eller ubehagelige lyder som kan brukes for å stanse en hund til å bjeffe.

Konklusjoner

Konklusjonene i denne rapporten er basert på gjennomgang av vitenskapelig litteratur.

Strømstøt er generelt sett ubehagelig både for dyr og mennesker. Opplevelsen kan variere fra å være ubehagelig til meget smertefull, avhengig av de elektriske spesifikasjonene utstyret har, situasjonen og individuelle faktorer

Bruk av vanlige strømgjerder har få ulemper siden gjerdet er synlig for dyra og de kan holde trygg avstand til gjerdet. Dette avhenger imidlertid av gjerdets utforming, plass og flokksammensetning. Muligheten for å takle virtuelle gjerder avhenger av at dyrene har fått tilstrekkelig opplæring og at varselsignalet fungerer som det skal. Enkelte arter og/eller individer lærer seg fortere enn andre hva et lydvarsel fra halsbåndet betyr, og hvilken atferd som skal til for å unngå strømstøt.

Automatisk fungerende elektrisk utstyr som er festet på dyret over en lengre periode innebærer fare for hudirritasjoner og funksjonsfeil med vedvarende støt. Engstelse kan være en årsak til at hunder bjeffer når de er alene. Strømstøt kan øke engstelsen. Bjeffehalsbånd med sitronsprut er minst like effektivt som elektrisk halsbånd i å dempe bjeffing hos hund. Det finnes noen indikasjoner på at halsbåndet med sitronsprut blir mindre effektivt over tid.

Fjernstyrte elektriske halsbånd er oftest en effektiv metode for å lære hunder ikke å jage sau, som er et viktig formål. Støtet er smertefullt for hunden og bruken kan innebære fare for feillæring. Treneren bør ha høy kompetanse. For generell lydighetstrening finnes gode alternative metoder som ikke innebærer ulemper for dyrevelferden.

Bruk av ku-trenere i båsfjøs eller drivstaver ved slakterier er problematisk fra et dyrevelferdssynspunkt. Kua kan ikke velge en annen oppholdsplass og uforutsette strømstøt kan skje.

Kunnskapshull og usikkerhet

Etter gjennomgang av litteraturen fant vi flere kunnskapshull angående de ulike typer elektrisk utstyr som brukes for å modifisere dyrs atferd. Forskning synes å legge mer vekt på effektiviteten av utstyret enn på effektene på dyras velferd. Vitenskapelig informasjon mangler i stor grad om hvor mange støt som trengs før dyr har lært hvordan det skal unngå fremtidige støt, og velferdskonsekvenser på kort og lang sikt både for dyr som har lært systemet og for de individene som lærer seint, eventuelt ikke evner å lære det.

Nøkkelord: VKM, Vitenskapskomiteen for mat og miljø, Mattilsynet, dyrevelferd, strømstøt, ubehag, smerte, straff, strømgjerder, virtuelle gjerder, lydighetstrening, kutrener, strømførende halsbånd, elektriske halsbånd, bjeffehalsbånd.

Abbreviations and/or glossary

Abbreviations

AC = alternating current

CNS = central nervous system

DC = direct current

Hz = Hertz, wave frequency

GPS = Global positioning system

J = Joule (unit for energy). In connection to electricity, 1 J is the energy needed to move an electric charge of 1 coulombe (=1 ampere in one second) through an electric potential difference of 1 Volt

NFSA = Norwegian Food Safety Authority

VKM = Norwegian Scientific Committee for Food and Environment

Glossary

Avoidance learning = learning to keep away from a particular stimulus

Cow trainer = an electrified metal rod placed horizontally above the back of the cow in order to make her step back before urinating and defecating

Conditioned learning = a learning process in which the animal associates two stimuli to elicit a new behavioural response. This involves pairing a conditioned stimulus (for example a light signal) with an unconditioned stimulus (for example electric shock) to produce a conditioned response (active avoidance). Eventually, the light signal (conditioned stimulus) alone will trigger a behaviour (conditioned response), trying to avoid getting shocked

Coprophagia = eating faeces

Electro-ejaculation = using electric stimuli to cause ejaculation

Learned helplessness = the animal has learned that it can do nothing to improve the situation, and remains passive

Neurotransmitter = a chemical signalling substance, which is released into the synaptic cleft, enabling transmission of signals between neurons.

Negative/positive reinforcement = reinforcement will increase the likelihood that a behaviour will occur in the future, by adding something pleasant (positive reinforcement, e.g. a food treat) or taking away something unpleasant (negative reinforcement, e.g. to remove the pressure on a rein)

Obedience training = teach an animal to do something on command

Punishment = punishment will decrease the likelihood that a behaviour will occur in the future. Positive punishment refers to adding something unpleasant, e.g. shouting or an electric shock. Negative punishment refers to the removal of something pleasant.

Stray current/voltage = the occurrence of unintentional electric pathways

Virtual fencing system = a technology that enables animals to be confined or moved without the aid of visual barriers within a defined area. The animal is equipped with a sensor, usually on a collar, which emits a warning signal, alerting it to stay away from the forbidden zone. An aversive stimuli (punishment) will follow unless the animal turns around.

Background as provided by the Norwegian Food Safety Authority

The Animal Welfare Act requires that animals shall be treated well and be protected from the danger of unnecessary stress and strains (§ 3). This is also specified in § 26 of this Act concerning the training of animals: "*Any person who trains animals (…) shall ensure that the animals (…) are not intentionally subjected to fear, injury or unnecessary stress and strains."*

It has been assumed that animals subjected to electric shocks experience strains, such as discomfort and possibly also pain, stress and fear. It is therefore considered illegal, in principle, to subject animals to electric shocks, with a few, strictly regulated exceptions. This applies to "cow trainers" in tie stalls, electric prods in slaughterhouses and electric collars used for training dogs to avoid livestock and wild deer. Such aversion training of dogs using electric collar is covered by a specific regulation and it can only be undertaken by qualified trainers.

The use of electricity is banned in indoor enclosure furnishings used to house cattle, sheep, goats, pigs and horses. However, electric fencing is allowed for outdoor use. The reason for this is that the fences are visible to the animals. In addition, outdoor areas are usually large enough for the animals to easily avoid contact with the fence. However, there is no general rule regarding the use of electric equipment on animals.

According to administrative practices, in principle, all types of equipment designed to automatically punish specific behaviours in animals are, regarded as being in defiance of the Animal Welfare Act. Until now, this has been an issue mostly concerning dogs, involving different types of "anti-barking" collars offered for sale. Such collars may also deliver other types of aversions, such as citronella scent, water, compressed air, etc. The main reason is that there is an acceptable risk that dogs are subjected to unnecessary strains, due to failure of equipment and lack of supervision, and the risk of punishing dogs for behaviours other than the ones intended.

Not necessarily all use of electric and/or automated equipment for the training of animals and controlling their behaviour is considered illegal. It will depend on the circumstances, for example, whether the advantages outweigh the disadvantages in a particular case.

Occasionally, new equipment is introduced and must be assessed. The Animal Welfare Act requires that *"anybody who markets or trades in new industrial methods, equipment and technical solutions which are used for animals, shall ensure that they are tested and found to be suitable, taking into account animal welfare"* (§ 8 second indent). Currently, the NFSA has no approval procedure for equipment used on animals. When new equipment is developed, for example, in order to control behaviour in animals, we have to assess whether or not proper documentation exists. This is part of our regular surveillance activity.

NoFence, a system where grazing animals (goats) are kept within specific GPS-defined areas by using automatic electric collars, is a current example of new equipment destined for use on a large scale. The system works by delivering a graded sound, warning the animal as it approaches the boundary of the defined area. If the animal turns around and moves in the opposite direction, the sound stops. If the animal continues, it will eventually receive an electric shock from the collar. For the time being, the NFSA considers the use of NoFence as illegal in most cases (according to the Animal Welfare Act § 3, § 26), even though we cannot preclude that there could be legal areas of application. Furthermore, the NFSA considers that the requirement to document suitability (according to the Animal Welfare Act § 8) is not fulfilled. The developers behind NoFence have presented two reports, which supposedly satisfies the requirement to document suitability (Animal welfare Act § 8). The Norwegian Veterinary Institute was previously asked to assess the scientific quality of these reports, and found that the documentation concerning impact on animal welfare was inadequate.

In order to better assess the animal welfare consequences of equipment exposing animals to electric shocks as well as automated equipment exposing animals to aversions, the NFSA needs an overview of documented knowledge on this subject.

Terms of reference as provided by the Norwegian Food Safety Authority

Request for summarized knowledge

Based on the dialogue concerning the request, NFSA and VKM have concluded that scientific data is scarce. A risk assessment would thus contain a high level of uncertainty and be of limited use.

Therefore, NFSA requests VKM to present a review report on the effects of using electric shocks to control behaviour on animal welfare . In addition, we would like VKM to summarize the current knowledge on automated equipment exposing animals to different types of aversive stimuli (discomfort). NFSA will use the report as a scientific foundation for surveillance and control and in the event of future amendments of relevant legislation.

1. NFSA asks VKM to summarize relevant research and current knowledge in this field, and to describe how animal welfare is affected by exposure to electric shock. For example, NFSA would like to gain more knowledge on how traditional electric fences, cow training, electric prods and attaching electric equipment on animals affect animal welfare.
   It is mainly livestock on pasture (sheep, goats, cattle, horses, alpacca and lama) and dogs that are subjected to electric shocks. However, we would ask VKM to present information on effects of the wider use of such equipment, if possible. Rangeland grazing livestock, other species kept outdoors (reindeer, elk, deer, roe deer), pigs, poultry and certain species kept as pets, could be relevant examples.

2. NFSA also asks VKM to summarize relevant research and describe how animals are affected by the use of automated equipment which subjects animals to aversive stimuli (discomfort), other than electric shocks. Such equipment may, for example, comprise various types of automatic «anti-barking collars» that release citronella scent, water, compressed air, etc.

Assessment

1 Introduction

1.1 About this review report

As mentioned in the terms of reference, NFSA and VKM concluded together that scientific data is scarce and that a risk assessment would thus contain a high level of uncertainty and be of limited use. This conclusion was made based on preliminary literature searches made by VKM in the period between February and March 2017. The searches revealed that most of the scientific data is based on short-term studies under experimental conditions. The data gaps revealed in this review report are highlighted in chapter 5.

This report is therefore not a risk assessment, but a review report on the effects of using electric shocks to control behaviour on animal welfare. In this opinion, VKM also summarizes knowledge on automatic equipment exposing animals to different types of aversive stimuli (discomfort).

In chapter 1, we describe the literature search and selection of literature on which we base this report. Physiological effects of electricity and how such aversive stimuli are used to adjust animal behaviour are also presented here.

Chapter 2 describes technologies or devices that are commonly used as punishment to adjust behaviour and their implications for animal welfare.

Chapters 3 highlights uncertainties related to studies conducted on the technologies or devices presented in this report.

In chapter 4, we address the terms of references.

1.2 Literature search strategy

All members of the project group conducted literature search using Web of Science, Google, Pubmed, and by searching on-line databases and libraries at the Norwegian University of Life Sciences as well as the Norwegian Veterinary Institute. No restrictions were set on date of publication. The project group also provided information based on their expertise on the topic that was, if relevant, included in the report.

Searches were made containing the following key words (and various combinations of): *welfare, electric, electrical shock, livestock, punishment, avoidance learning, virtual fences, cow trainer, electric collars, electronic collars, anti-barking device, electric goad, electroejaculation, electroimmobilization, anti-crib biting*

Titles of the articles obtained after searching were screened for relevance by the project group, in relation to Terms of reference. Citations in the reference lists of relevant articles were also scanned for further information. Data gaps that were uncovered during the literature review process is described in chapter 5.

1.3 Bioelectric signalling

Electric signals are an integrated part of normal physiological and biochemical processes in the animal body, e.g. the function of the heart (Sjaastad et al., 2003). Information is sent as electric impulses, action potentials, along the nerve cell from various types of receptors to the central nervous system (CNS) and back from the CNS to effector cells, e.g. muscles. The voltage across the neuronal axon membrane is 70 mV, and the velocity of action potentials varies from 1-120 m/s, depending on the myelinization and also the diameter of the neuron. Between neurons are synapses in which released neurotransmittors excite or inhibit transmission across the synapses. Further, processing of information in the brain depends on such electrochemical signals. The positive or negative electric charge of molecules is essential for transportation and metabolism. Thus, the function of the animal body is totally dependent on electricity. The mammal body constitutes of approximately 70% water with dissolved electrolytes, and electric current is easily conducted through most body tissues. Exceptions are e.g. adipose tissue and dry hair/wool/feathers, which are good insulators.

1.4 Aversiveness of electrical stimulation

Endogenous electric currents will stimulate nociceptors in the skin. Electric stimulation above a certain threshold is perceived as aversive by humans and animals and, depending on the stimulus strength, the experience may vary from unpleasant to very painful. In addition to physical electrical parameters, both physiological and psychological factors of the animal may affect pain perception and reaction to electric shock (Tursky, 1974). The unpleasant feeling (i.e. pain) is present even when the motor reaction to the stimulus is reflexive, i.e. the withdrawal response after touching an electric fence comes immediately, before the event is perceived consciously. The aversiveness of electric shock has been shown for various species, even in invertebrates like honeybees (Vergoz et al., 2007).

1.4.1 Behavioural and physiological indicators of reduced animal welfare

Pain is a subjective experience and as such, it cannot be measured directly. Behavioural and physiological indicators of stress are therefore used. Behavioural signs of acute pain include vocalizations, withdrawal, flight, freeze reactions, aggression, reduced activity, altered facial expression or body position (Broom and Fraser, 2007). The most common behavioural signs of pain will vary with species. For instance, while dogs often vocalize, sheep usually remain silent. Examples of physiological indicators of pain/stress are heart rate, heart rate variability, and stress hormones. The pain may also be followed by a feeling of fear/anxiety.

When faced with a challenging situation, individuals within a species may respond differently to the same aversive stimulus. Individual differences in stress responsiveness have impacts on how and how well the animal copes with an aversive event. The stress response can be divided into three steps: 1) recognition of an aversive stimulus, for example an electric shock), 2) changes in physiology and behaviour to counter the threat and 3) the consequences of activated stress response (Moberg, 2000). The last step, in particular, determines the long-term impact on animal welfare. Koolhaas et al. (1999) described distinct stress responses as coping styles, defined as "a coherent set of behavioural and physiological responses to a challenge that is consistent over time and across contexts and that is characteristic of a certain group of individuals". Studies on rodents under laboratory settings have shown that individuals respond with distinct behavioural patterns, when being shocked by an electrified probe (Koolhaas and Van Reenen, 2016). In response to the electric shock, individual mice either froze or buried the probe using the bedding material in the cage. Both freezing and burying behaviour may interpreted as different types of coping styles or even distinct expressions of fearfulness, according to Koolhaas and Van Reenen (2016).

Compared to other unpleasant stimuli, e.g. the use of noise, even the highest non-damaging level of noise was far less aversive for rats than the shock intensities typically used in the laboratory (Campbell and Bloom, 1965). Electric shock has many experimental advantages that have made it commonly used as a pain stimulus in the laboratory. It is easy to apply, the strength of the stimulus is measurable, it can be controlled very accurately as the current can be turned on and off very precisely, the concurrent pain is intense and short-lasting, tissue damage can be avoided, the equipment is cheap, and the trials/results are easy to reproduce (Tursky, 1974).

1.5 Effects of electricity on the body

The Ohm's law describes the relationship between voltage, current and resistance. Current is measured in Ampere (A), Voltage in Volt (V) and resistance in Ohm (Ω).

Current = Voltage/Resistance

The voltage is a measure of the potential energy over the system, the difference in charge between two points. The current is the movement of electric charges (charge per unit time) through the conductor. If the voltage is kept constant, the current strength will depend on the resistance of the conductor. The resistance describes how easily or difficult current flows through the material. For instance, current passes easily through metal but not wood. Metal and water are good conductors, whereas wood and rubber are not.

The equation above oversimplifies the situation when talking about live animals and is not directly valid for live tissues, even though the principle is the same. The current which passes through the conductor (e.g. animal tissue) between two points (e.g. the skin touching the electric fence and the foot on the ground) will depend on the voltage across the two

points (the fence and the ground) and the resistance in the system (how well the conductor, i.e. the animal tissue, leads current) when the animal body becomes a part of the electric circuit. If a horse touches the electric fence with its muzzle, the current is led through the head, via the body and limbs to the ground. The resistance in this circuit will be lower and the current and experienced shock larger, should the horse wear iron shoes and/or the ground is wet. By contrast, if the sheep's fleecy chest comes in contact with the fence, the animal may not notice any shock because the wool acts as an insulator. Interestingly, although the current is led through the body, the sensation of pain is limited to the body part that is in direct contact to the fence (Whiting 2016).

In live tissues, the resistance is called impedance and is special in that it is not constant. Rather, it will be reduced during the first seconds of exposure to the current. The second shock to the same body location may therefore be experienced as more painful than the first (e.g. Duker et al., 2002) because more current passes the tissue. On the other hand, the endogen opioid system, which modulates pain perception, is activated by electric shocks. Thus, the last shocks in a row may be sensed as less painful (Fanselow and Bolles, 1979).

Different properties of the current have an effect on the perceived pain and also the startle response of an electric shock. Wave frequency (measured in Hertz) is one of these. In a human study, Duker and colleagues (2004) found that test persons had a significantly stronger startle response and reported significantly more pain when wave frequency increased from 30 to 60 Hz, and from 60 to 90Hz. Impedance is influenced by wave length. Grimsbø (2016, PhD thesis) found that in fish, combined impedance for fish and equipment in a system increased, when wavelength was increased from 40 to 60Hz. Then, it flattened to 800 Hz, decreased above 800 Hz and became negligible at 1MHz. Alternating current (AC) has a tendency to result in paralysis and direct current (DC) more often leads to strong muscle contraction.

Contact with low voltage equipment results in currents that usually are not dangerous, unless exposure lasts for many seconds. Contact with high voltage equipment may be very dangerous. Such accidents are more common in human beings. The muscles contract and the person may not be able to move the hand to disconnect the electric circuit and is thus exposed to currents for an extended period. Muscle contractions may be strong enough to cause fractures and tendon injuries. It is not uncommon that animals on pasture are struck by lightning and die. In 2016, more than 300 wild reindeer died in one lightning incidence in the mountains of Norway (https://www.aftenposten.no/norge/i/Mp7kM/322-reinsdyr-drept-av-lynnedslag-pa-Hardangervidda). The current from high voltage equipment (>1000 V) and lightning is very strong, and even exposure lasting for a fraction of a second may be dangerous. Serious acute effects include cardiac arrest and respiratory failure, and there may be internal burns and damage to vessels (including thrombosis), skin, muscles, skeleton, kidneys and the nervous system (including hearing problems) and traumas from falls (Veiersted et al., 2003). Damage to the nervous system can first appear after an extended period of time. The effects will further heavily depend on the route of the current. For example, if current passes the heart, there is an increased risk for heart complications.

Electric machines in the household typically operate at 50-60Hz, a wave-length which increases the risk of heart fibrillation.

1.5.1 Electrostunning and electrocution

Electricity is used in slaughter plants to stun species such as sheep, goats, pigs, poultry and fish before bleeding. Current of sufficient strength, which is applied across the brain, will cause a reversible loss of consciousness. Some equipment additionally passes current through the heart of the animal, causing cardiac fibrillation/arrest, which reduces the risk of regaining consciousness. Electricity may also be used to kill, e.g. farmed foxes. In such circumstances, electrodes are placed in the mouth and the anus of the fox so that the current passes both through the brain and the heart (VKM et al., 2008). Electricity is further used in traps to kill mice and rats. At least some of the electric traps are not designed to lead current through the brain and will not produce immediate loss of consciousness. Rather, the current passes from foot to foot and may cause pain, cardiac arrest and loss of posture, before the head comes in contact with the electrode. The use of electricity for stunning/killing will not be further discussed in this report.

1.6 Effects of predictability and controllability on stress responses

Electric shocks have been widely used as a standard aversive stimulus in the laboratory, e.g. in the study of stress. It is well established that predictability and controllability are highly important factors that can help an animal to cope with adverse events. Signalled (i.e. predictable) electric shocks result in lower stress response compared to randomly delivered (i.e. unpredictable) shocks. For instance, rats that received a signal before being shocked developed no or reduced number/severity of stomach ulcers, in contrast to rats that received the same number of shocks but without preceding warning (Seligman, 1968; Weiss, 1971). Dogs that were able to associate the electric shocks with their own action, and consequently were able to predict and control the stressor by changing behaviour, had lower stress responses, measured as heart rate and cortisol levels, compared to dogs that were given the same amount of shocks, but out of context (Schalke et al., 2007). Thus, to get a warning signal that precedes a shock is less stressful than receiving random shocks. To be able to control the situation, e.g. by pressing a lever to switch off the current or to escape to another compartment, is also perceived as less stressful than a situation where the animal knows that it might receive a shock but can do nothing about it. This is true even when the actual exposure to current is identical in the two groups.

In a human study, Grillon and colleagues (2004) showed that the degree of aversiveness of the unpleasant stimulus is very important. They compared electric shock and air blast as aversive stimuli and found that unpredictability only resulted in higher levels of reported anxiety with the more aversive stimulus.

Repeated unavoidable shocks may lead to "learned helplessness" (Seligman 1968; Maier and Seligman, 1976), a passive, depression-like state.

1.7 Avoidance learning and obedience training using electric shocks

In animal training, electricity has been used as punishment for incorrect behavioural responses. Due to its aversiveness, electricity has shown to be very effective. However, to be effective in learning, a punishing stimulus must be contingent with the behaviour it is intended to suppress (McLean and Christensen, 2017). Using remotely controlled electric collars, the punishment can be delivered very accurately, which is an important advantage. Electric devices include automatically functioning equipment (e.g. virtual fence systems, anti-barking collars and cow trainers) and equipment actively used by an operator to teach the animal a task (e.g. obedience training). Electric devices can also be used to extinguish an inherent or acquired unwanted behaviour (e.g. chasing sheep) by forming strong negative associations with a behaviour, which otherwise is rewarding. Avoidance learning using electric shocks have formerly also been tried as therapy in human beings, such as treating alcoholism (Cannon and Baker, 1981; Cannon et al. 1981) and to reduce self-injurious behaviours in mentally retarded and autistic persons (e.g. Duker et al., 2004).

In general, addition of an aversive stimulus to punish an animal is cautioned because of some well-documented side effects, reviewed by McLean and Christensen (2017) in horses. For example, the authors mention effects like lowered motivation to try new behaviours, learned helplessness, learned fear reactions which may be inerasable, deleterious emotional changes, negative associations with the punisher, learning deficits and post-traumatic stress disorder, which result in latent aggression.

One major drawback of using electric shock as an aversive stimulus is that a strong association may be formed between the shock and a non-intended event, and if established, may be very difficult to extinguish (Christiansen, 2000).

The Norwegian Animal Welfare Act prohibits in § 26c the use of training methods that deliberately inflict fear, damage or unnecessary suffering in animals. Harsh methods in animal training is also covered by § 14a, which prohibits the use of violence. Thus, the Acts urge a shift towards positive training methods. In dog training, the use of punishment for undesired behaviours are increasingly being replaced by the use of positive reinforcement (e.g. treats) for desired behaviours. This trend is also seen in horse training, where punishment is being replaced by negative reinforcement (the reward is the removal of a pressure, e.g. from the rein) and, to a lesser extent, positive reinforcement.

2 Use of electrical equipment and effects on animal welfare

In this chapter, various types of equipment or devices that produce electric shocks intended for use on domesticated animals are presented and the potential impacts on animal welfare are described, based on available scientific literature.

It should be noted that all types of equipment are prone to malfunction. Failure of electric equipment that results in unintended delivery of shocks to the animal would result in very poor animal welfare.

A section that covers aversive stimuli other than electric shocks concludes the chapter. All equipment or devices are summarized in table 2.9.

2.1 Electric fences

Electric fences are commonly used to control the movement of pastured animals in Norway. They are cheaper than conventional fences because they do not have to be robust, impenetrable barriers, which require considerably more time and materials to erect (Howard, 1977; McKillop and Sibly, 1988). Electric fences were actually first used in World War I to contain prisoners-of-war (Storer et al., 1938). According to McAtee (1939), electric fences were used all over USA as early in the 1930-ies in wildlife management, mainly to keep bears, buffalo, deer etc., outside of agricultural land or to keep cats away from pheasant farms. Storer et al. (1938) presented data on the use of electric fencing to keep bears away from apiaries and provided some details about the construction of the electric fence. McKillop and Sibly (1988) gave a more updated list of 44 species that had been managed by electric fencing.

Electric fencing can be used to keep wild animals, e.g. deer, out of agricultural land and gardens, and predators away from pastures for agricultural animals. However, electric fences are mainly used to keep domestic animals within the borders of the scheduled pasture area. Electric fences are used for goats (e.g. Kilgour and Dalton, 1983), sheep (e.g. Howard, 1977), cattle (e.g. Howard, 1977), outdoor pig production (e.g. Honeyman et al., 2003) and horses (e.g. Glauser et al., 2015).

McAtee (1939) provides some concerns about the quality of the electrical equipment (power supply for the fence), and the problems with lethal electric shocks. Electric livestock fences are designed to be non-lethal. However, deaths do occur if the animal is trapped in the fence. Other authors also confirm that the early fence control units were dangerous and unreliable (e.g. Dalziel and Bruch, 1941; Dalziel, 1944; Pharoah, 1976). Later, the fence control units were improved, making the technique more acceptable (e.g. Flanagan, 1983). Lethal electric fences still have a limited use in the Far East for the control of rodents (e.g.

Ramos, 1970). Non-lethal fences rely on their effectiveness on animals changing their behaviour as a result of receiving an unpleasant electric shock.

Electric fence designs have been developed largely by trial and error (McKillop and Sibly, 1988), the main aim being to use as little fencing material as possible to keep costs low. Positioning of the fence and the number and spacing of wires are some of the design factors that determine whether an animal will receive an electrical shock. Although the voltage is usually very high, up to many thousand volts for a large enclosure, the current (amperage) is low. The electricity is sent in pulses (every 2-10 seconds) and there is a fixed limitation for maximum current (Wikipedia), and so it is not dangerous for humans or animals. A relatively simple electric fence may allow the farmer to control large animals that otherwise would require very solid fences or barbed wire. The apparatus is connected to the electrical system of the farm or to a car battery, and generates several thousand volts.

The Norwegian regulations for the keeping of cattle, the regulations for the keeping of sheep and goats and the regulations for the keeping of horses prohibits the use of electrical wires on pen partitions inside, but provides no information about the use and design of electric fences or virtual fences outside. There is no information in the Norwegian regulations for the keeping of pigs concerning the use of electrical wires, such as pen partitions or electric fences outside. According to the regulations provided by the Swedish Board of Agriculture (in Swedish, Jordbruksverket), the use of electric fences on pasture for farm animals is not prohibited in Sweden.

DeLaval is among the companies supplying electric fences for livestock. The electrical apparatus for electric fences provides 5000 V, which is sent in pulses every 2-10 seconds. Limits are set to the maximum delivery of current, that it is not dangerous for humans or animals. The current strength delivered far out on the fence might be lower than close to the apparatus, depending on the electrical resistance in the wire and any vegetation that touches it. There is a European norm for electrical fence energizers*: Household and similar electrical appliances - Safety - Part 2-76: Particular requirements for electric fence energizers (IEC 60335-2-76:2002, modified + A1:2006).*

Not all species are easy to keep within a fence. According to Kilgour and Dalton (1983) the main problem with farming goats on free range systems is usually fencing to control animals. Goats are agile and can climb up the stays that support fence posts and climb over. They can negotiate eight-wire fences that normally hold sheep and they can find holes and expand holes in and under the fence.

2.1.1 Effects of electric fencing on animals

The association between pain and incidental contact with the fence is rapidly made. Cattle will usually learn to avoid the physical electric fence in less than three challenges (Mckillop and Sibly, 1988; McDonald et al., 1981a). The visual electric fence offers the animal controllability in the sense that it can actively choose to keep a safe distance to the fence

and avoid the aversive stimulus (McKillop and Sibly, 1988). The most usual response to electric shock is flight. According to the list of species reviewed by McKillop and Sibly (1988), only porcupines did not react with flight. Flight away from the fence is a typical behavioural response and usually causes no management problems. However, the animals should be provided with enough space to turn around without fleeing into the fence on the other side, e.g. in a corner. However, flight across an electric fence will be problematic. This has been observed in deer (Floyd, 1960) and coyotes (e.g. Thomson, 1978), although most observations did not report flight towards the electric fence in either deer or coyotes (e.g. McAtee, 1939).

Some individual animals may also exhibit defensive anti-predatory behaviours, such as biting, butting or clawing. Such reactions are rare, though, and cause few limitations to the use of electric fences (McKillop and Sibly, 1988).

Surprisingly, there seems to be no data on the effect of the magnitude of the shocks from electric fences on the animals. Interestingly, McDonald et al. (1981b) observed that it took up to six days after turning off the power before animals passed under the wire.

In a study over 7 days with cattle that had no experience with electric fences, McDonald et al., (1981a) showed that 90 % of the shocks were received on the first day, 47 % of the cattle never received an electric shock, 37 % received one shock and the remaining animals received two and three electrical shocks. Another similar group of cattle was first trained in a small paddock with a conventional fence and with an electrical wire inside for half a day. This group received an average of 2.05 electric shocks in the training period, but during the next 7 days only one of the animals got one electrical shock. In another study of cattle that had no experience with electric fences (Bartay et al., 1979), all shocks occurred within the first day. Around 25 % of the animals never received electric shocks and 30 % received one electric shock. Martiskainen et al. (2008) investigated the time for dairy bull calves to learn to avoid a light built electric fence. The number of electric shocks was gradually reduced to day 4. They concluded that the bull calves learned to avoid the electric fence quickly.

Glauser et al. (2015) studied stress responses in horses kept in large (36 m^2) and small (12 m^2) paddocks and with conventional and electric fences. They concluded that "based on physiological parameters there is no indication of stress in electrically fenced paddocks. However, horses in electrically fenced paddocks use less of the available area, especially by avoiding the area near the fence."

In a handbook for outdoor pig production (Honeyman et al., 2003), the authors stated that a single strand electric fence is sufficient to contain pigs weighing more than 11 lb. Smaller pigs cannot be contained by an electric fence unless netting is used. A pig that is naïve to an electric fence will not always jump back when shocked, but rather lung forward and may break the wire. Thus, they recommend a training pen with an outer conventional fence.

Several investigations have focused on strip grazing, especially for cows. However, none of these studies seem to show concern for the welfare of the animals, being forced to forage so

close to the electrical wire. A welfare problem may occur with electric fences if the animal is very hungry and there is fresh grass on the other side. We could not find any scientific papers on how electric fences affect animal welfare of goats or sheep.

Electric fences can be used to control the movements of several wildlife species (e.g. McAtee, 1939; Storer et al., 1938). The main focus is to keep these animals away from for example orchards, domestic prey animals or apiaries. However, no data on their reaction to the electric fence is provided. Hone and Atkinson (1983) reported that in feral pigs, 61 % of all the electric shocks were received with the first 30 minutes of the 100 h observation period. Further, in a study of feral goats in a training yard, most shocks were received during the first two days, and the goats were considered to be trained after 7 days (Niven and Jordan, 1980).

2.1.2 Design of electric fences

In many cases the electric fence consists of a single electrical wire (or ribbons with a steel thread woven into the mesh). Multiple wire fences are sometimes recommended for animals, such as goats (Kilgour and Dalton, 1983). Niven and Jordan (1980) designed a four-wire electric fence for goats and compared it with a conventional fence. The authors concluded that while it is difficult to contain feral goats within conventional fencing, they were successfully kept inside using this type of electric fence. Also for sheep, a multi-wire system or netted fencing is sometimes recommended (Flanagan, 1983), partly because this can also protect the animals from dog attacks. Electric, netted fences are commonly used for sheep in Norway. Pigs might flee through the fence if the lower electric wire is mounted too high, and the shock is received on the back.

Some species form stronger dominance-based hierarchies than others. In domesticated pigs, for example, the cost of living together in groups may sometimes lead to competition for space and food resources amongst individuals, potentially triggering social stress and aggressive behaviour (Mendl et al., 1992). Mixing groups is a common practice in modern pig husbandry and often causes intensive aggression in commercial housing systems in pigs. Aggressive behaviour may occur in most species, when space and/or attractive resources are limited. Electric fences could represent potential welfare problems under such circumstances, especially for subordinate individuals that may be chased straight into the fence.

When designing electric fences in pastures, attention must also be paid towards eliminating stray current/voltages (i.e. unintentional electric pathways) from occurring (Reinemann, 2009). For example, a wet branch hanging down from the fence into a water device may electrify the drinking water. This unintentional electric shock may result in the animal associating drinking water with punishment, thus becoming both anxious and dehydrated. Such scenarios can be problematic from a welfare perspective.

2.2 Virtual fences (with electric collars)

A virtual fence has no visible parts, only invisible boundaries. Systems used for family dogs have an electric wire which is buried along the boundary. With modern technology, these boundaries may be set without any physical wires, instead the boundaries can be drawn and changed on a computer. The target animals wear a collar with a GPS.

Development of virtual fencing systems is seen as having future benefits for e.g. cattle management (Anderson, 2007). For extensive systems in which there are few fixed fences, virtual fencing would enable greater control over grazing and optimisation of pasture use. In intensive farming systems such as dairy, there would be reduced labour input, shifting electric fencing for strip grazing. Fay et al. (1989) writes that goats are useful for bush and weed control, and that their usefulness would be enhanced if their distribution on grazing land could be controlled without herders or permanent fencing. Virtual fencing systems may even be used for pastures on outlying fields in mountain areas.

Umstatter (2011) has put together a comprehensive review on the development of virtual fences, and points out that the concept of virtual fencing systems is increasingly discussed among those who manage free-ranging animals. Virtual fences are more flexible, less costly to construct and maintain compared to conventional fences. However, Umstatter (2011) claims that there is a perception, especially in Europe, that the main aversive stimulus, an electrical stimulus, is problematic in terms of animal welfare.

In 1971 a patent was filed by Peck (1973), describing a method for controlling a domestic animal (mainly cats and dogs) wearing a receiver circuit. A signal-emitting wire was placed on the ground to surround a predetermined area. This product is still available under the name "Invisible fence". Fay et al., (1989) tested the system on goats and found that five out of six goats could be successfully trained to avoid the electrical shock. Monod et al., (2009) conducted experiments between 1999 and 2003 with a similar system on cattle. A more sophisticated system, without any wire, is patented by Brose (1990) and involves distance zones from a central point.

Umstatter (2011) also pointed out that a disadvantage with a virtual fencing system can be the equipment that is attached to the animals. They have to carry the device, usually a collar with a GPS and a battery that produces an electrical stimulus (see 2.3 for more info). Wearing this rather large and heavy collar may cause skin irritations and soreness. The animal can also become trapped e.g. by a feeder or another physical structure. The collar might also have to be adjusted as the animals grow. To avoid these negative effects, Rose (1991) described an implant in the nose or upper lip of the animal. The implant is especially suited for domestic cattle and sheep. Quigley (1995) described a virtual fencing system, which is incorporated in the ear tag of livestock animals, such as cows, sheep, pigs, goats and horses. The system works with audio warnings and electrical stimuli. Quigley's system was tested on 90 cross-bred yearling steers by Tiedemann and colleagues (1999). They performed two trials. In the first, the correct response rate was as high as 93 %. In the

second, the correct response rate was only 67 % as a result of the ear tags not operating correctly.

In 1999, the first patent on fenceless animal control using the GPS-system (Marsh, 1999) was filed. This system also uses audible signals, such as conditioned warning and electric shocks as aversive stimuli. Furthermore, a virtual GPS-based fence system was tested through pilot studies on cattle in 2006 (Butler et al., 2006). However, most of these pilot studies used remote control to manually elicit the stimuli. Later, several other patents on virtual fences, also based on GPS technology, have been filed. Interestingly, according to Umstatter (2011), none of the inventions on virtual fences, apart from the invention known as the "Invisible Fence", are currently commercially widely exploited. In Norway, the virtual fence system "Nofence" has been tested for sheep, goats and cattle (described further in the next section).

2.2.1 Effects of virtual fencing using electric shocks on animals

The majority of virtual fence systems utilize audio warning sounds and electrical stimulation as punishment (Umstatter, 2011). However, long-term responses by cattle to fenceless control systems have not been studied extensively. One of the animal welfare concerns is that the electric shocks can be repeated unintentionally, due to technical problems like faulty collars, or that the animals do not get a chance to learn before they receive the electric shock. Lee and colleagues (2008) studied the effect of low energy electric shocks (600 V, 250 mW) on cattle. The researchers found that the effects on cortisol, β-endorphin, heart rate and behaviour were minimal and similar to that induced by physical restraint in a crush. Furthermore, Lee and colleagues (2009) did an experiment with five heifers using GPS-collars. The animals would receive a sound when entering the exclusion zone, followed by an electric shock (600 V, 250mW) if the animal kept moving in the same direction. At the third week, significantly fewer electric shocks were delivered. Hence, the authors concluded that an appropriate sound is an effective conditioned stimulus for virtual fencing for cattle.

Markus et al. (2014) compared electric fences and simulated fenceless control in an experimental set-up. The heifers wore halters with an electric remote-controlled device, and no auditory warning cues were used. Unfortunately, the main aim of this study was to look at the responses of cattle after the systems were deactivated. The authors concluded, however, that cattle can remember locations where aversive events have taken place.

In a recent study, Umstatter and colleagues (2015) tested a commercially available system (Agrifence, Henderson products Ltd, Gloucester, UK) on 10 cows. An induction cable on the ground represented the virtual fence line and the cows were fitted with Boviguard collars (no information on electrical shock magnitude is available). Umstatter et al., (2015) concluded that "the system successfully prevented the cows from crossing the virtual fence line". No changes in their general activity or lying behaviour were observed.

Brunberg and colleagues (2015) examined a virtual fencing system on 24 pregnant ewes. The ewes were tested three times, one by one, in a test arena. Only 37.5 % reached the learning criterion and successfully associated the sound signal with the electric shock (4000 V, 0.1 J, 0.2 s). When the successful ewes were tested in small groups, the median number of electric shocks was around two on day 2 and almost zero on day 3. In a recent study, Brunberg et al. (2017) investigated the functionality of Nofence technology (see Background as provided by the NFSA). In the first experiment, three groups of three ewes with lambs were tested in an experimental enclosure with one virtual fence border. The mean number of electric shocks delivered per ewe was reduced from 4.4 on day 3 (when the outer physical fence was removed) to 1.5 on day 4 (when the virtual border was moved). In the second experiment, 32 ewes with and without lambs were divided in four groups. The experimental pen had three physical and one virtual fence side. The plan was to replace one physical fence with one virtual fence per day. On day 1, 71% of the ewes received the maximum number of shocks on day 1 and 77% on day 2. Since none of the groups reached the learning criterion, the experiment was terminated after day 2. The authors concluded that "it is too challenging to ensure an efficient learning and hence, animal welfare cannot be secured. The Nofence prototype was unable to keep the sheep within the intended borders, and thus cannot replace physical fencing for sheep". There were technical challenges with the collars that the authors suggest may have affected the results.

Jouven et al. (2012) tested a training protocol for ewes in a pen set-up using dog-training equipment. They found that ewes quickly learned to associate the warning sound with impending punishment (electric shock) after a couple of contacts with the punishment zone. Furthermore, tests with a social attractant resulted in a few trained ewes crossing the virtual border to rejoin their peers in the "forbidden zone". Jouven and colleagues (2012) concluded that "virtual fencing can be used to alter the distribution of grazing sheep within large fenced areas, but cannot replace conventional fences for absolute control".

Fay et al. (1989) used the virtual fence system on goats and found that the goats learned the system. In Norway, virtual fences are currently in use on nearly 100 commercial goat farms. A behavioural study examining the effects of this virtual fencing system (Nofence) was conducted in autumn 2017 on 10 commercial flocks of goats (4-20 goats per flock) during a 7-day observation period (Eftang and Bøe, 2017a). The shock was preceded by a warning sound comprising a tone scale with a duration of 5 – 20 seconds. The goats with previous experience of wearing these collars received a mean number of 0.4 electric shocks per animal per day (range 0.07 – 0.98). The maximum number of electric shocks during the whole 7-day period was 29 for the goat receiving most shocks. Observations on six groups of goats without any previous experience with virtual fences showed that in four of the groups the mean number of electric shocks decreased to less than 0.5 per animal per day at day 3 after introduction. The maximum number of electric shocks received by one animal during the whole observation period was 38. Most goats that received an electric shock for the first time responded by running a short distance before resuming grazing. On the first days, many animals run out of the area, but this number was low after the training period was completed. The animals received no shocks (or warning signals) upon returning.

An initial controlled study on six heifers on pasture using virtual fencing (Nofence) was also conducted in autumn 2017 (Eftang and Bøe, 2017b). The magnitude of the electric shocks was the same as for the goats (Eftang and Bøe, 2017a). The authors observed that the heifers learned to associate the warning sounds with the electric shocks already at day 2. After some days, however, some individuals started to cross the virtual boundary and apparently ignored the shocks. These behavioroural responses were, according to the authors, probably due to the shocks not being aversive enough in order to contain the heifers within the area. Inspectors from the NFSA characterised the heifers' reaction to the electric shock as slightly unpleasant.

2.2.2 Alternative aversive cues

Butler et al. (2004) used various sounds that are potentially frightening to cattle, in an attempt to replace electrical stimuli. The authors concluded, however, that the sound cues were not very effective. Also, Umstatter et al. (2009) performed an experiment where aversive sounds replaced electric shocks. The authors found some very good responses, but these were not consistent enough. In a study by Umstatter et al (2013), they tried to control the location of cows using broadcast audio, and placed loudspeakers at 10 m intervals. They compared "irritating" high frequency sound (8000 Hz, or a mix of 8000 and 10 000 Hz) with acute alarming sounds (dog barks and human cry). They found the two sounds to be equally effective to reduce the use of pasture in the zones close to the loudspeakers. The authors concluded that the use of irritating sounds as aversive stimuli is valid and is potentially an option for the development of virtual fences, although not as stock-proof as a conventional fence.

2.2.3 Limitations with virtual fences

Umstatter (2011) also pointed out that one of the urgent issues with virtual systems is the limitation of battery supply to keep the system running, and to develop the system to ensure safety and animal welfare. The risk for dysfunction of equipment, causing unintended and long-lasting shocks must be minimized. Another potential problem with virtual fencing systems relates to the size and shape of the containment area of the animals. Similarly, as with designing electric fences (see section 2.1.1), attention must be paid to mixing the animals in appropriate group compositions, in order to reduce social stress and aggression between individuals.

2.3 Electric collars in dog training

Electric collars can be used to modify behaviours of various species. Electric collars can be part of a virtual fencing system for livestock (see 2.2.) and invisible fences used for dogs, where the collar is activated at a boundary line to keep the animal within a defined area. In this section, electric collars used for dog training purposes will be examined, although such collars may be used for other species.

An electric collar is a collar with a battery attached to it, and has two blunt electrodes protruding towards the neck. The current passes from one electrode to the other via the skin and causes an electric shock. The strength and length of the shock can usually be regulated and adjusted to the situation.

Some dog trainers find electric collars effective and useful, while others find them inhumane and therefore do not use them (Ziv, 2017). As mentioned in the introduction, an electric collar may have either 1) an automated functioning aimed to prevent some undesirable behaviour from occurring or 2) be operated manually using a remote-controlled transmitter in an active training situation. In the first situation, the animal wears the electric collar permanently or for an extended period of time (for example, in virtual fencing systems or to prevent dogs from barking). In the second situation, the animal usually wears the device just during the training session, except for during the habituation period.

Remote controlled electric collars are used in two main situations. Firstly, they are used in aversion learning, where the training goal for the dog is to form a strong and lasting negative association with a certain behaviour, e.g. to chase sheep, or with the sheep itself, in order to abolish any motivation to approach or to chase sheep in the future (Christiansen, 2000). Secondly, the electric collar may be used in obedience and daily life training to punish an inappropriate behaviour or undesired response (Blackwell et al., 2012). Then, the electric shock is used as a punisher, much the same way as the trainer reinforces a correct response, in specific learning tasks. In Norway, there is a directive regulating the use of electric collars in dog training (FOR-2008-03-14-256). It states that the use of electric dog collars is generally forbidden, except for avoidance learning to prevent dogs from chasing/killing grazing domestic animals, semi-domesticated reindeer and wild cervids. A further condition is that training can only be performed by certified trainers. However, it is legal to sell the equipment.

An English survey (Cooper et al., 2010) investigated the manuals and the electrical specifications of a selection of 13 commercially available electric dog collar models, representing nine different brands from a total of 170 different models which were marketed under 14 brand names, all found in an internet search in 2007. Collars had varying combinations of two to four functions, which could be controlled from the handset. These included a sound signal, a vibration signal (both can be used as a warning signal reminding the dog that a shock may come, if it does not change behaviour), a short electric shock (each stimulus lasting 0.5-420 milliseconds), and a continuous stimulus lasting as long as the button on the handset is pressed (all except one model had a maximum time limit, being 7-13 seconds). The impedance of the dogs was modelled as a passive resistance with a value about 10 kΩ (range 4-150 kΩ) for wet dogs and 600 kΩ (range 22-950 kΩ) for dry dogs. There were large differences between the selected models in the voltages, number of pulses and the length of each stimulus. Voltage pulses per second in the continuous stimulus varied from 10-1000. Most collars had 8-10 stimulus levels available, but some had more than 100. For most models with more than one stimulus duration or number of pulses, the value increased as the strength of the shock was increased on the handset. The collars probably

gave a fixed current strength (amperage), as the peak voltage varied with the resistance of the dog, from 100 V at 5 kΩ to 6000 V at 500 kΩ. Manuals were considered clear on how to operate them, but the authors found that the information provided on how to use the collar in dog training was variable and often poor.

Blackwell et al., (2012) made a survey among English dog owners addressing the use of electronic collars. A total of 3897 questionnaires could be analyzed (response rate 27%). Among the respondents, 0.9% reported to use electronic boundary fences (i.e. invisible fencing), 1.4% anti-barking collars, and 3.3% reported the use of remote controlled shock collars. For the latter group, the reason for use given was mainly problems with recall and chasing livestock or wildlife, but included general training purposes, chasing bikers, other dogs and cats, pulling the leash, aggression, eating faeces, escaping, and jumping up.

Masson and colleagues (2017) performed a similar survey in France. Dog owners (n=1251) were recruited using an online questionnaire. Among the owners, 26% reported to use electric devices; 11.9% anti-barking collars, 4.5% electronic boundary fences, and 14.2% remote controlled shock collars (which were predominantly used for recall problems). After using electric collars, owners described their dogs' behaviour as less excited, calmer or sadder.

Polsky (1994) reviewed advantages and disadvantages of using electric collars, covering remote controlled collars, anti-barking collars and collars for boundary training. The advantages the author listed for using electric collars included the ability to rapidly suppress an undesired behaviour, the ability to administer punishment, and the ability to facilitate a behavioural response. Disadvantages included random discharge of shocks, problems with applying correct timing of shocks, delivery of incorrect intensity or duration of stimuli, behavioural regression after the collar had been removed, shock-induced aggression, and lesions on the neck. Polsky concluded that shock collars should be used by experienced users only, when all other options to solve a behavioural problem have tried and failed. Schilder and van der Borg (2004) addressed a commonly made mistake by trainers when shock collars were used in the education of guard dogs: the command was followed by a shock so quickly that the dog was unable to respond adequately to prevent the shock. Thereby, the dogs learned that a command from the handler predicted getting a shock.

Another welfare concern is the risk of technical dysfunction resulting in unintended shocks or shocks lasting longer than intended. Especially for electronic equipment fitted on the animals for an extended period of time and without the owner present, e.g. virtual fencing collars and anti-barking devices, the welfare consequences of such errors are large (Christiansen, 2000). Blackwell et al. (2012) also addressed the potential for abuse, if the owner activates the device in anger.

2.3.1 Anti-barking collars

Barking is a natural behaviour of dogs. They bark for different reasons, such as when left alone to call on family members, when feeling lonely, anxious or bored. Dogs also bark to alert family members, for instance of a perceived danger. Some dogs bark when chasing prey, e.g. hares and roe deer. Others bark when positively excited, for instance when welcoming a family member or during play. There are both individual and breed differences on the predisposition to bark. Excessive barking may be annoying for the surroundings, but can also indicate welfare issues (Raglus et al. 2015).

The anti-barking collar has a sensor placed on the larynx. The current strength is usually quite low. The collar automatically emits a short electric stimulus when the dog barks. This punishment results in the dog suppressing its barking behaviour.

Masson et al. (2017) found that neighbour's complaint was the main reason to use anti-barking collars. It was used mainly on dogs that showed excessive barking beforehand, and only 25.5% of the users reported success. A side-effect of the use of the collar was that skin burns were reported in 10.7% of the dogs.

Unintentional delivery of electric shocks represent a risk factor. For example, the collar may be activated when the dog vocalises to welcome its owner returning home. Consequently, the dog may learn to associate family members coming home with pending punishment.

Norway's supreme court (HR-2017-1250-A) evaluated the use of an electric anti-barking collar on a dog in a case in 2017. The dog had first been equipped with a collar emitting a strong shock lasting for 20-30s, causing panic in the dog. The court concluded that such a collar is illegal according to Animal Welfare Act §14 on violence. The dog owner had thereafter used another electric collar giving a short and less painful shock. The use of this collar was discussed relative to the lower threshold of what can be considered violence. The court stated that permanent use of the electric anti-barking collar was not a necessary nor a proportional tool and that using such a collar on the dog, even when the batteries were later removed, caused anxiety and stress that is forbidden (according § 14). The verdict was 15 days in prison.

2.3.2 Avoidance learning

As explained above, the aim of avoidance training is to establish a strong negative association between the painful shock and an otherwise self-rewarding behaviour, like chasing sheep. Here, the current used is relatively strong, and there is little doubt that this is a painful experience for the dog. Common reactions are vocalizations, lowered body position and/or sudden halt or flight.

Avoidance learning using electric shock collars to teach dogs not to chase and kill sheep is considered effective in dogs, although there are age and breed differences (Christiansen et al., 2001). The practice in Norway is that avoidance training towards sheep is run by local

hunters' and sport fishers' organisations (Norges jeger- og fiskerforbund). The training is usually open for non-members and for all breeds except polar dogs (e.g. Greenland dogs), which are denied access. The reason for this is said to be that these breeds have a very strong hunting motivation, which can hardly be eliminated, and that aversion training could give the owner a false belief that the dog is "sheep-proof". Nevertheless, the method has been suggested for coyotes (Linhart et al., 1976; Andelt et al. 1999).

Dale et al. (2017) reviewed the efficacy of using electric shocks to reduce predation by dogs on the New Zealand native bird kiwi, which is unable to fly. The study included 1647 training sessions over nine years involving 1156 dogs of various breeds. Training stimuli comprised stuffed or frozen dead kiwis, kiwi manure, nest material, and a two-dimensional kiwi image. At the second session, 69% of the dogs showed avoidance, and at the fifth session 100% showed avoidance. Dogs that were old at first training and dogs with a long (more than three years) gap since last training showed lower levels of avoidance.

In avoidance training, e.g. towards sheep, the goal is that the dog associates the unpleasant electric shock to sheep in general, resulting in the dog avoiding all sheep in the future, independent of situation. The dog should therefore not associate the shock with the specific training area, a specific sheep or group of sheep (e.g. white sheep), wearing a particular type of collar, any other item or happening which the dog might have focused on or experienced when being shocked, or presence of any human being. The knowledge and skills of the trainer is therefore essential. The trainer must be able to interpret the dog and the situation to be able to time the delivery of shock correctly. The shock should inhibit the motivation to attack and be given when the dog shows an intention to approach or attack the sheep. Otherwise, the shock may unintentionally inhibit a desired behaviour. This is a difficult task, and Christiansen et al. (2001) was critical to the quality of the licensing system for trainers to be allowed to use shock collars.

Once an incorrect association is established, it may be very difficult to rectify it. For instance, when an electric shock collar is used for teaching a pointing dog to remain standing or to sit down and not run after a grouse when it takes off, the dog may associate the pain with the event prior to this. Unintended associations can be formed with the moment before the bird flies up, when the dog correctly and on demand advances from the “freeze” position, and not actually the act of running after it. Consequently, some dogs become very reluctant to advance to rise the bird.

2.3.3 Use of shock collars in obedience training

Previously, electric collars were used by the Norwegian police and military personnel during the education of police/military dogs. Electric shocks were used as punishment for unwanted behaviours, as described above. This is still a routine in many other countries.

Schilder and van der Borg (2004) studied short and more long-term behavioural effects of training guard dogs with the help of shock collars. They observed reactions of 32 police dogs

receiving a total of 107 shocks during training. The most common disobediences from the dogs resulting in a shock were: not obeying the "let go" command, the dog heeling ahead of the handler, the dog biting the "criminal" at the wrong moment, and the dog reacting too late on the command "heel". The dogs' immediate reactions included lowered body posture (e.g. ears, tail down), high pitched vocalizations, avoidance, redirected aggression, and tongue flicking indicative of stress, fear and pain. Most reactions lasted only a fraction of a second. Moreover, Schilder and van der Borg (2004) compared the behaviours of 16 dogs that had received shocks during training in the recent past with 15 control dogs that had received similar training but never received shocks, but nevertheless were given rather harsh handling including physical corrections. None of the dogs received electric shocks during the study period. All 31 dogs were observed in the training arena under free walk (on a leash), obedience training and during "man-work", and in a park at free walk and under different obedience exercises. During free walk, obedience training and "man-work" in the arena, previously shocked dogs showed a lower ear position compared to controls. This difference was also found in the park situation. Significantly more of the previously shocked dogs showed tongue flicking compared to controls, and the behaviour occurred more often in the training arena than in the park. The authors concluded that being trained was stressful for the dogs, that receiving electric shocks was painful and made training even more stressful, and that the dogs had learned that the presence of the owner/handler and his voice announced the reception of shocks, even outside the normal training grounds.

The questionnaire study by Blackwell et al. (2012) revealed that recall problems were a common reason for dog owners to use electric collars. The owners were asked about their opinion on the success of using different training techniques for recall and chasing problems in their dog. Here, 97% found rewards to be successful, whereas 83% found shock collars and 94% other aversive measures, to be effective.

Cooper et al. (2014) investigated welfare consequences of using remote control shock collars in recall training of family dogs. In a preliminary study on shock collars used on nine dogs with a history of chasing sheep, they recorded behaviour and physiological stress indicators. The reaction to the shock was described as a sudden change in locomotion, from walking or running to halt or a distinct change in direction. During the following period the dogs showed an increase in vocalization, had a lowered tail position, were more tense, showed more yawns and paw lifting, and engaged less time in exploratory behaviours and more time in contact with the owner. Also, salivary cortisol levels were increased. In the main study, consisting of 63 dogs referred to professional trainers to solve recall problems, Cooper at al. (2014) compared three groups of 21 dogs: The first group used shock collars, the second did not (trainers for both these groups were experienced in using shock collars), and the third group were trained by trainers using reward based methods only. In this larger study, the stimulus strength for the electric collars was lower than in the preliminary study, and pre-warning cues were used. Dogs were trained for 2x15 minutes per day for 4-5 days and the sessions were videotaped and cortisol was assessed. The shock group spent significantly more time being tense, yawned more and engaged less in environmental interaction than the reward group. The shock group tended to pant and vocalize more. No significant

differences in salivary or urinary cortisol were found between the groups. Among owners, 92% reported improvements in obedience following training, with no difference between groups. However, owners of dogs trained with electric collars were less confident in applying the method themselves, 76.2% versus 94.7 (without shock) and 100% (reward based, only).

In the training of pointing dogs (e.g. setters, pointers) in Norway, it is known that the use of electric collars does occur, especially to teach the dog to stop or sit down when the bird takes off. However, we have not found scientific literature on the effects of this on dog welfare, except for the common anecdotal saying that some dogs become very reluctant to rise the bird on command. (see section 2.3.2)

2.4 Cow trainers

The cow trainer consists of an electrified rod mounted horizontally and crosswise over the cow's back when standing in a tie stall. When the cow arches its back to urinate or defecate, the back will come in contact with the rod and the cow will receive an electric shock. The cow is supposed to learn, by trial and error, to step backwards in order to avoid the electric shock. Hence the stall surface will be kept cleaner, the udder and skin will stay cleaner and the need for cleaning by the stockperson is reduced.

The use of electrical cow trainers is prohibited in some countries (e.g. Sweden) and regulated in other countries (e.g. Norway, Switzerland). Article 35 Paragraph 4 of the Swiss Animal Welfare Ordinance states that the following provisions apply when using cow trainers (Norwegian legislation given in brackets):

a. Only cow trainers adjustable to the individual animal are permitted (Norway: similar wording).

b. Cow trainers may only be used with cows and animals over 18 months of age (Norway: for lactating cows only, not allowed around calving, during heat or when the animal is sick).

c. Only power supply units suitable for cow trainers and approved according to Article 7 Paragraph 2 TSchG (Animal Welfare Act) may be used (Norway: NEMCO-certificate required which documents voltage and pulse energy; energy maximum 0.1 Joule, maximum 3000V; power should automatically be disconnected if more than four shocks are given within a short period of time).

d. The length of the standing stall shall be at least 175 cm (Norway: Stall length not given).

e. The distance between the withers and the cow trainer shall not be less than 5 cm (Norway: at least 50 mm above the back, and 0.6-0.8 m behind cubicle front).

f. The power supply units shall be switched on for not more than two days a week (Norway: Should not be connected to power longer than necessary to keep the stall clean).

g. The cow trainer bar shall be moved to the upper position a few days before birth until seven days after birth (see c)).

Moreover, Article 35 Paragraph 3 of the Swiss Animal Welfare Ordinance states that no new standing stalls shall be installed with cow trainers in the future for bovine animals.

In practice, there are indications that the individual adjustment of the cow trainer, requested by the legislation, are not always followed in practice. Bakken and Gudding (1977) investigated cow trainers in a random sample of commercial dairy farms. They found a huge variation in management practices regarding individual adjustments among the farms, and with regards to the use of power supply units (and thus the strength of shocks). Incorrect adjustments were common, and some cows had the cow trainer mounted so low that they were forced to stand in an unnatural position, with lowered back, or on one side of the stall to avoid being shocked. However, this study was performed before the legislation was enforced and at a time with less emphasis on animal welfare than today.

Nevertheless, the use of cow trainers is an accepted practice in other countries, for example Canada. A field study among 317 tie-stall farms in Ontario (Zurbrigg et al., 2005a) showed that cow trainers were regularly used in 76 % of the herds. In Norway the use of cow trainers was comprehensive in the early 1990s (Bøe and Østerås, 1996). Since then, many Norwegian dairy farms have constructed new buildings for loose housing, in which cow trainers are not used. Norwegian regulations require that all herds should be loose housed by the year 2034. Hence, the number of farms with tie stall housing will continue to decrease. Non-official data from TINE indicate that the majority of Norwegian dairy farms still have tie stalls, although the majority of cows are kept in loose housing systems.

2.4.1 Cleanliness

Several investigations have found that the presence of a cow trainer improved the cleanliness of the udder and hind limbs (e.g. Gjestang, 1980; Bergsten and Pettersson, 1992), although Zurbrigg and colleagues (2005b) actually found the opposite. The authors explained this by pointing out that the position of the trainer relative to the stall bed and the height of the trainer above the cow's back were not recorded in their study (Zurbrigg et al., 2005b). This information is important since several studies claim that proper placement of the trainer is imperative for the trainer to work effectively (Bergsten and Pettersson, 1992; Busato et al., 2000).

In a small controlled study, Gjestang (1986) found that the cleanliness of the cows got worse when the current for the cow trainer was reduced from 6500 V and 1200 V to 549 V. Further, the proportion of dunging in the dunging area (behind the solid stall floor) was

highest for the highest current (6500 V), nearly zero without the cow trainer and 20 % using the cow trainer without a current (power supply turned off).

2.4.2 Exposure

Metzner and Groth (1979) found that the frequency of touching the cow trainer (eliciting an electrical shock) decreased from 5 – 22 times per day when introducing the trainer to 0 – 4 times per day within a two-week period. Hultgren (1991) recorded only two to three contacts between the cow and the cow trainer the first five days, and after day 5 no contacts were recorded. In this experiment the power supply, Alfa Laval Nervus Mini-Master, providing 2000 V at 60 pulses per second. Surprisingly, no other investigations report the actual number of contacts made between the back of the cow and the trainer, and hence the number of electric shocks elicited. According to the Swiss regulations, the power supply should not be switched on more than two days a week, indicating that the cow trainer has an effect also when no electric shock is provided. Hultgren (1991) described the cows reaction after touching the cow trainer as local twitching of the skin or no visible reaction at all.

These studies describe reduced physical contact with the cow trainer over time, under controlled experimental conditions. However, the situation may be different in actual production settings, especially if the cow trainers are not properly adjusted.

2.4.3 Effects on animal health, behaviour and animal welfare

Bergsten and Pettersson (1992) found that the prevalence of both heel-horn erosions and interdigital dermatitis was significantly lower in cows in stalls with cow trainers.

Oltenacu and colleagues (1998) used data from > 15000 Swedish dairy cows in 150 herds and found that exposure to electrical cow-trainers increased the risk of silent heat, clinical mastitis, and ketosis and changed silent heat from a neutral disease with respect to culling. Bakken and Gudding (1977) reported that farmers experienced more teat damage, that rising behaviour was negatively influenced, and that cows seem to be more uneasy or nervous in barns with cow-trainers. Based on a survey in 328 Norwegian dairy herds, Bakken (1982) found that the frequency of sub-clinical mastitis was higher in herds with cow-trainers.

Data from Denmark (Alban et al., 1996) showed that constant use of the cow trainer was associated with the highest risk of hock lesions. A study in Canada by Zurbrigg and colleagues (2005b) observed that the prevalence of hock wounds was significantly higher for cows housed in tie stalls with cow trainers, however, they had no effect on hind claw rotation/ lameness.

Østerås and Lund (1988) found no effect of the use of cow trainers on bovine udder health, based on data from 158 dairy herds in northern Norway. Regula et al., (2004) found no effect of the use of cow trainers on health and welfare in a survey on Swiss dairy farms.

Busato et al. (2000) found that the presence of cow trainers in Swiss organic dairy herds tended to increase the frequency of soft-tissue and claw injuries, and joint injuries were significantly more frequent.

In an early study on the effect of cow trainers, Metzner and Groth (1979) monitored lying behaviour, hearth rate and blood pressure. No effects on lying behaviour and serum enzymes were found, however, there was an increase in hearth rate and blood pressure on the first and second day after exposure to the cow trainer. The authors concluded that there was "no objection, for physiological or ethological reasons, to use cow trainers". However, in a study comparing two cows exposed to cow trainers and two cows not exposed, Hultgren (1991), found that there were more lying down movements and abnormally slow lying-down movements in the cows exposed to the cow trainer. Furthermore, the cows exposed to cow trainers also showed a higher frequency of interrupted lying-down sequences.

Unintentional shocks from the cow trainer may occur if, for example, the animal licks its back or stretches its body after rising up. This may result in the cow learning to restrict its locomotion and grooming behaviours even further. Although such behavioural responses are sometimes observed in stalls, we could not find any scientific studies on this.

2.5 Electric goads

Electric goads (prods) are used by handlers in many slaughter plants to move animals which are balking or otherwise unwilling to move in the right direction. Here, the sensation of pain on the rump or hindquarters will cause the animal to attempt to escape from the pain by moving forwards. The need for coercive means to drive animals depends heavily on construction and maintenance of raceways and pens (see www.grandin.com). Personnel are allowed to use electric goads also in Norway, but their use is regulated. Studies on pigs have shown that exposure to electric prods increases the number of vocalizations and also has physiological effects, such as an elevated heart rate, increases in blood lactate and salivary cortisol levels (Benjamin et al., 2001; Correa et al., 2010; Hemsworth et al., 2002). A survey, conducted at 23 beef harvest plants in USA, reported a higher usage of electric prods on beef loads (32.4 %) than dairy loads (15.4 %) during cattle transportation (Nicholson et al., 2013). Broom (2003) stated that the use of electric prods as driving aids may cause undue stress and pain to the animal.

According to the Norwegian regulations (Forskrift om avliving av dyr, 2013), the use of electric goads to move animals should be avoided as much as possible. If electric goads are used, the animal should not be subjected to more than maximum two short shocks and at least 10 seconds should pass before prodding is repeated. Furthermore, the animals should have free access to move forward.

Temple Grandin is a well-known international expert on handling facilities in slaughter plants. Based on welfare audits on several slaughter plants (Grandin, 2012), she commented that the use of electrical goads is, in general, significantly reduced in USA. Most plants have completely banned the use of electrical goads for unloading and moving animals. Grandin's recommendation is that people should not routinely carry electrical goads, but the use should not be totally banned either.

2.6 Miscellaneous

2.6.1 Use of electric shocks for immobilization

Electricity can be used to immobilize animals and humans. In fact, the development of electro-shock weapons used by e.g. police and military forces was intertwined with the development of electric cattle prods (Rejali, 2001). Electroshock weapons combine the effect of pain with freezing (immobility). In Norway, electricity for immobilization has been used in fishing, mainly for research or wild fish management purposes. Electricity may cause a broken spine in some fish, as the electric stimulation results in strong muscle contractions, and fish in general have a weak skeleton relative to muscle strength.

Using a small electric current (e.g. a commercial equipment using 55 V DC 20-240 mA with 1 ms pulse repeated 50 times/s, referred to in Grandin et al., 1986), the skeletal muscles contract and the animal cannot move. In a number of countries, electro-immobilization has been or is still used to control animal movement under various farm procedures and even during surgery, rather than anaesthetizing the animal. For instance, in Canada, the cervid industry used it when removing soft antlers. In 1996 the first position statement discouraging the use of electro-immobilization was passed by the Animal Welfare Committee and Canadian Veterinary Medical Association, the primary concern being pain (Whiting, 2016). Grandin et al. (1986) studied the relative preference in ewes for electro-immobilization or mechanical restraint in a chute which squeezed and tilted the animal. Electro-immobilization was clearly more aversive than the alternative. Lamboy (1985) looked at electro-immobilization of calves, sheep and pigs, and Pascoe and McDonell (1986) in adult dairy cattle and the authors suggested that the procedure was aversive. A recent review (Hynd, 2017) finds considerable evidence that high-intensity current, producing tetanic contractions are aversive and probably painful for sheep.

However, electrical stimulation may in some cases have analgesic effects. Hynd (2017) suggested that transcutaneous neural stimulation which is a very high-frequency, randomly variable current application, has some pain-relieving effects that may last for up to hours, days or even weeks post-treatment. Electro-narcosis is known from humans for surgical purposes (Geddes, 1965), and has been reported in rats (Mantz et al. 1992), using transcranial simulation with low currents (4-10 microA). Further, direct transcranial stimulation of low frequency inhibited pain reflexes in rats (Wilson et al., 1989) and this method is even used in humans to relieve pain.

2.6.2 Anti crib-biting

In horses, crib-biting and/or wind-sucking are abnormal, stereotypic behaviours that for many years were called stable-vices. Today, we know that these behaviours can be elicited by factors such as stress and frustration due to social isolation, early weaning, confinement, too little roughage and too much concentrate. However, many horse owners still believe that the behaviour is "contagious". Therefore, many different means have been used (and still are) to prevent the behaviour from being displayed. These include the use of tight neck collars that physically prevent the horse from using the necessary neck muscles, electric collars, as well as electrifying surfaces which the horse uses in order to be able to perform crib-biting. Shocks will stop the horse from performing crib-biting but will probably increase the level of frustration and stress. A rebound effect is observed when the horse is again given the opportunity to crib-bite, demonstrating the high internal motivation to crib-bite (McGreevy and Nicol, 1998). Some horses will develop wind-sucking, which is swallowing air without the need to fixate the jaw towards a horizontal surface. Due to welfare concerns, McGreevy and Nicol (1998) suggest that horses should not be prevented from crib-biting, but rather be given adequate foraging opportunities.

2.6.3 Electro-ejaculation

The collection of sperm is a routine procedure in animal breeding. In Norway, this is done by using a live female animal, another male, or a phantom to tease the male animal (e.g. stallion, bull, ram) to mount and then lead the penis into an artificial vagina. Alternatively, especially in smaller species, masturbation of the male animal may be used. However, in some countries, electro-ejaculation is routinely used to collect semen. Palmer (2005) describes the procedure for bulls. He states that most modern electro-ejaculators use a sine-wave pulse at 20-30 Hz. The maximum voltage of a popular model is 16V with a maximum current of 0.9 A. With most bulls, ejaculation occurs with pulses below 8 or 9 V. Bulls should be restrained during the procedure. A transrectal examination and massage for 10-60 s is followed by insertion of a probe. Electric stimulation is applied until there is a slight contraction of the muscles of the hindlimbs, and then stopped. This is done successively, and the voltage is steadily increased and held for 1-2 s, followed by a 0.5-1 s rest. The bull's reaction, like muscle contractions, struggling, vocalization and occasional recumbency, are indicative of discomfort and pain. Further, physiological indicators of stress and/or pain are present, for example increased heart rate, cortisol levels and temperature (Ungerfeld et al., 2017; Abril-Sanchez et al., 2017a; 2017b).

Electro-ejaculation has been used in Norway on wildlife, but then under general anaesthesia.

2.7 Alternatives to shock collars in dog training

There are other automatically functioning collars, which are designed to stop inappropriate barking. Most of these emit citronella odour, while others use scentless spray or a sound.

2.8.1. Anti-barking collars using citronella or scentless spray

Steiss et al. (2007) studied 24 barking kennel dogs in three treatment groups; electric anti-barking collar, citronella collar and control. Dogs wearing anti-barking collars barked less than controls on the second day and they did not bark at all on the third day. There were no significant differences between the electric collar and citronella groups. The collar dogs (both electric and citronella) had a higher cortisol level compared to control dogs on the first day, however the difference was not significant.

Juarbe-Diaz and Houpt (1996) compared two commercially available anti-barking collars and found that the citronella collar was more effective in reducing barking (88.9%) compared to the electric collar (44.4%). Most owners expressed a preference for the citronella collar and believed that it is more humane.

Moffat et al. (2003) compared the effect of collars with citronella spray (30 dogs) to a scentless spray (29 dogs) and a control group (collar with no anti-barking function) among hospitalised/kennelled dogs. The dogs showed a 76.7% and 58.6% decrease in barking for citronella and scentless spray, respectively, which was significant compared to controls.

Wells (2001) found that citronella collars reduced barking, but that the dogs eventually habituated to the scent so the effect was gradually reduced. The reduction in effectiveness came more slowly if the dogs wore the collar intermittently.

2.8.2 Other unwanted behaviour

Coprophagia (eating faeces) is not uncommon among dogs, and both shock collars and other aversive stimuli have been used in order to eliminate this undesired behaviour. Wells (2003) studied 28 dogs which ate their own faeces and fitted half of them with a citronella spray collar and the other half with a sound collar. Both treatments resulted in a significant decrease in the behaviour during the first week. In the citronella group, this decrease continued whereas dogs in the sound treatment group subsequently increased the behaviour.

2.8.4 No-pull harnesses

The use of collars with spikes and choke collars to prevent or reduce pulling the leash, by causing discomfort, is nowadays being replaced by other means, e.g. different no-pull harnesses fitted on the body or head collars (similar to halters used for horses). Grainger et al. (2016) found that dogs with flat collars and no-pull harnesses did not show signs of stress when walked.

2.8.3 Alternatives to aversive cues in dog training

In a review on the use of aversive training methods in dogs, Ziv (2017) concludes that owners/trainers should rely on positive reinforcement methods and avoid using positive punishment and negative reinforcement as much as possible. Herron et al. (2009) concluded that confrontational methods can lead to aggressive responses, and Deldalle and Gaunet (2014) found that aversive techniques may hamper the dog-owner relationship. Today, modern learning theory has resulted in reward (e.g. food treat) based training methods, which have become very popular among dog trainers, both professionals and private, as they have shown to be highly effective (Pryor, 2006). Fukuzava and Hayashi (2016) and Okamoto et al. (2009) found that food is a more effective reward than praise or petting. Chindetti et al. (2016) found that using a food treat alone was just as effective as using a conditioned stimulus, e.g. a clicker.

Protopopova et al. (2016) demonstrated that contingent remote delivery of food decreased home-alone barking significantly for three out of five dogs, and that it was possible to gradually reduce the food delivery later without losing effect. Raglus et al. (2015) studied 25 nuisance barkers and interviewed their owners. They found a negative correlation between barking frequency and the amount of general obedience training received by the dog. Thus, more interaction/activity with the dog might alleviate barking problems.

2.8 Summary

Table 2.9. List of technologies or devices used to alter animal behaviour and consequences on welfare.

Technology/Device	Aversive stimuli	Punishment intended for:	Potential negative impact on animal welfare
Electric fence system	Electric	Learn to stay within a visible barrier	Probably insignificant after the first painful encounter(s) if appropriate fence design, stocking density, group composition and feeding
Virtual fence system (with collars)	Electric, with warning signal	Learn to stay within defined, invisible boundaries. Animals receive a warning prior to punishment, allowing for behavioural adjustment	Pain and stress due to a more difficult learning task, individuals with learning problems, unintended shocks due to malfunctioning devices, physical injuries from the collar
Electric collar in dogs, remote control, under active training	Electric, with or without warning signal	Avoidance learning (e.g. sheep), obedience training in various contexts	Pain and stress. Human errors during training; incorrect delivery of shock causing more stress, anxiety and various behavioural problems
Cow trainer	Electric	Learn to step backwards to keep the stall and animal clean	Pain and stress. Learning problems? Increased risk of some health issues like clinical mastitis, ketosis, teat and hock lesions, silent heat. Abnormal behaviours during lying down/standing up.
Electric goads	Electric	Coerce to move forwards	Stress and pain
Device(s) for immobilization	Electric	N/A	Probably pain
Anti crib-biting	Electric or tight collar, electrified surface	Prevent crib-biting	Pain, increased stress levels because the need to crib-bite increases
Electro-ejaculation	Electric	N/A	Discomfort and/or pain

Technology/Device	Aversive stimuli	Punishment intended for:	Potential negative impact on animal welfare
Anti-barking collar	Electric (with or without a warning signal), citronella odour, scentless spray, sound	Inappropriate barking	Pain and stress, depending on the aversiveness of stimulus
No-pull harness	Physical discomfort	Undesirable pulling	Probably insignificant

3 Uncertainties

After reviewing the literature, uncertainties remain in the following areas:

- Information on electrical technical parameters, e.g. the strength of the electric stimulation is often lacking in the literature, making comparisons difficult.
- There are very few studies investigating the long-term effects on animal welfare
- Studies observing the effects of cow trainers on animal health, behaviour and welfare has yielded contradictory results.
- One of the urgent issues with virtual fences concerns optimisation to further ensure safety and animal welfare. This includes studies on how fast the animal learns to avoid the shock in the training period and the degree of subjectively experienced control later. Furthermore, there is a need to prevent and control malfunctioning, e.g. prevent long lasting electric shocks if technical failures occur.
- Alternative aversive stimuli, such as sounds, in virtual fencing systems have yielded inconsistent results with regards to effectiveness.
- Studies comparing the effects of anti-barking collars, i.e citronella vs. electric shocks have yielded inconsistent results.

4 Conclusions (with answers to the terms of reference)

1. **NFSA asks VKM to summarize relevant research and up to date knowledge in this field and to describe how animals are affected by exposure to electric shocks and the impact for animal welfare. For example, NFSA would like to gain more knowledge on how traditional electric fences, cow training, electric prods and attaching electric equipment on animals affect animal welfare.**

   It is mainly livestock on pasture (sheep, goats, cattle, horses, alpacca and lama) and dogs that are subjected to electric shocks. However, we would ask VKM to present information on effects of a wider use of such equipment, if possible. Rangeland grazing livestock, other species kept outdoors (reindeer, elk, deer, roedeer), pigs, poultry and certain species kept as pets, could be relevant examples.

The scientific literature on equipment or devices that subject animals to electric shocks vary. Many studies tend to focus more on the efficiency (or lack of) of the technology, rather than the effects on animal welfare. Drawing clear conclusions by comparing the aversiveness, especially from a long-term perspective, between equipment is challenging and should be done with some caution. Therefore, the answers to Terms of reference presented here are based on summarizing scientific information, collected from the literature search, rather than an assessment by the project group.

Electric shocks are highly aversive to animals and humans, although the pain that is experienced may be very transient and obviously depends on the strength and duration of the stimulus. There is usually no physical damage caused by electric shocks from equipment that is designed to modify the animal's behaviour. Usually, the current delivered by the equipment can be adjusted to the situation, so that the shock is not stronger than necessary. Because of its aversiveness, the use of electric shock is a very efficient learning tool. Strong associations between a behaviour or event and the shock (i.e. pain) are quickly made. This is at the same time a drawback if an incorrect/unintended association is formed.

Equipment that exposes animals to electric shock and the potential consequences on animal welfare is addressed below. For a more in-depth discussion on these topics, we refer to chapters 1 and 2.

Electric fences - impacts on animal welfare

Except for the pain received at the first contact with the electric fence, there are few negative effects on animal welfare. The situation is predictable and can easily be controlled, two factors that are highly important in reducing stress and increasing coping. The shock is received only upon contact with the fence and the animal is able to keep a safe distance to the fence. Consequently, animals quickly learn to avoid contact with the electric fence, usually within two shocks. Potential risk factors, such as hunger (and at the same time spotting feed across the border), animals getting entangled in the electric fence or exposure to stray voltage, may still represent challenges to animal welfare.

Virtual fences – impacts on animal welfare

For the virtual fence to function as a barrier, the animals have to learn how to avoid electric shocks. The learning phase is probably stressful since more shocks are needed to achieve learning criterion, compared to visible electric fences, and every shock received is causing discomfort or even pain. The animal must learn to associate a warning stimulus (usually) emitted from the collar with the impending punishment (shock), unless it changes direction, e.g. makes a U-turn. When this is learned, the animal will be able to control the situation and should cope well. There seems to be both species differences and individual differences in learning capacity. In general, sheep seem to have difficulty with learning the system, whereas goats perform quite well. Norwegian studies confirm that there are individual differences in goats in how many shocks are needed before the connection is made and the goat knows what action it must take to avoid being shocked.

Potential risk factors, such as hunger (e.g. spotting feed across the border), problems related to lack of perceived control on how to avoid shocks, malfunctions in collars leading to shocks delivered out of context and physical injuries if the animal gets trapped by environmental obstacles may still represent challenges to animal welfare. As with ordinary electric fences, individuals could be chased into the punishment zone by more dominant group members or by predators. Collars that animals wear for an extended period of time might cause skin irritations, especially if the collar is heavy or tightly fitted.

Electric collars in dog training – impacts on animal welfare

In contrast to virtual fencing systems, aversion learning with dogs through the use of remote controlled electric collars is restricted to shorter periods of time, e.g. during the training session. Although a very efficient method during obedience and aversion training if used correctly, there are also several disadvantages, with direct implications for animal welfare. For example, in aversion training, unintended associations may arise from incorrect timing of the

shock relative to the intention of the dog. In obedience training, incorrect timing of command versus delivery of shocks may result in a dog that associates the actual training arena or the command itself with punishment, rather than the undesirable behaviour. Further disadvantages described in the literature include shock-induced aggressive behaviour, less exploratory behaviour, and more behaviours indicative of stress. Skin burns inflicted by the collar are also described. The success of training dogs using electric shocks as punishment is highly dependent on the skills and knowledge of the handler.

A specific concern with shock collars with automated function is that shocks may be delivered unintentionally or out of context. For instance, if the anti-barking collar is activated when the dog vocalises in response to its owner returning home from work, the dog may learn to anticipate punishment when the owner comes home.

Cow trainers – impacts on animal welfare

As with anti-barking collars in dogs, cow trainers are also used to modify natural cattle behaviour for specific purposes in tie stalls. In this context, the purpose of the cow trainer is to keep the stall surface and the cow clean. The cow trainer is an electrified metal rod mounted a few centimeters above the animal's back. This device is used to train the cow to step backwards before arching its back to urinate or defecate. Cows have been observed to reduce their physical contact with the device over time, indicating that they have learned how to avoid the shock. Since the cow trainer is used on an animal that is already placed in a very confined space, unintentional shocks can occur. Concerns have been raised regarding the impact on animal welfare. Negative health ffects, such as increased risk of mastitis, reduced fertility, and higher prevalence of hock lesions and claw injuries have been documented. Changes in behaviour, like abnormally slow or interrupted lying down movements, have also been observed. However, other studies report no effects or better claw health from using cow-trainers. Incorrect adjustment of cow trainers is a concern on commercial farms, causing more electric shocks than reported in scientific studies.

Electric goads – impacts on animal welfare

Using electric goads as aids in forcing animals to move forwards is advised against, due to animal welfare concerns. It is generally acknowledged that electric prods cause pain and stress and should therefore be avoided, if possible.

Devices for immobilization – impacts on animal welfare

In some countries, electricity has been used to immobilize or restrain animals during surgery. However, there are indications that this is experienced as more aversive than alternative procedures, such as mechanical restraint, in animals like

pigs, sheep and calves. Exposure to current in such contexts is likely to induce pain in the animal.

Devices against anti crib-biting – impacts on animal welfare

Crib-biting occurs in some horses that are kept stabled, which indicates shortcomings in the environment. Attempts at suppressing such stereotypic behaviours are sometimes made by horse owners. Several measures are used, for example equipping the animals with electric collars or electrifying the surfaces that they need to perform the behaviour. Horses subjected to shocks under these circumstances may respond with wind-sucking, a modification of the same stereotypic behaviour. The development of stereotypic oral behaviours, like crib-biting, could possibly be prevented through improvements in the environment, including sufficient foraging enrichment.

Devices used to stimulate ejaculation – impacts on animal welfare

Semen collection through electro-ejaculation is not used on livestock in Norway. Behavioural and physiological responses that are indicative of discomfort and pain has been observed in bulls. The method has been used in Norway on wildlife for research purposes, under full anaesthesia.

2. **NFSA also asks VKM to summarize relevant research and describe how animals are affected by the use of automatic equipment, which subjects animals to aversive stimuli (discomfort) other than electric shocks. Such equipment may, for example, comprise various types of automatic «anti-barking collars» that release citronella scent, water, compressed air, etc.**

The literature is divergent on the effectiveness of electric anti-barking collars compared to alternative less painful, but still aversive, methods. Descriptions of the effect on animal welfare is often lacking. In general, different methods are effective in reducing barking. Most studies find that citronella has an effect on reducing barking, that may be as effective as or even better than electric shocks. One explanation for this could be that as electric shock is more painful, it increases the dog's level of anxiety and thus increases the motivation to bark. However, the results across studies are not always comparable because information on current strength is not always given. Scentless spray has also been reported to reduce barking, albeit to lesser extent than citronella. Few studies have looked at long-term efficiency of the devices, however, there are indications that dogs habituate over time to the less aversive methods.

Few studies have been done on alternatives to electric shock in virtual fencing systems but the results so far indicate that they are less effective.

5 Data gaps

In this chapter, we describe the data gaps that were uncovered during the literature review process. These are scientific data on how electric shocks or alternative aversive stimuli affects animal welfare. Table 5-1 highlights these data gaps and the consequences if the knowledge and data would be provided.

Table 5-1. Data gaps and the consequences if information is provided.

Data gaps	Consequences if data gaps are filled (for VKM, the assigner, and/or the society)
Learning data for different devices, including individual variation in learning ability/time to achieve learning criterion: How many shocks are needed before the animal learns how to avoid further shocks	Such data are necessary to evaluate the negative welfare consequences in the training period, and be sure that a vast majority of animals are capable of learning the task. This knowledge is even important for society to be able to compare benefits and costs (for both animals and other parties) across alternative methods.
The amount of exposure in the long-term, after a training period, e.g. the number of shocks being elicited when cow-trainers are used in tie stalls.	Such data are necessary to evaluate if the shock delivery is predictable and controllable for animals exposed to the device.
The long-term efficiency (regarding the purpose) and long term impacts of electric shock on animal welfare	Such data are necessary to evaluate the long-term animal welfare consequences, e.g. on normal behaviours, affective state, and health. Further, data on the long-term efficiency relative to the purpose is essential. If for example, use of cow trainer leads to both chronic stress and more teat injuries/mastitis, it can be argued that the equipment does not function as intended, even if the lying area is cleaner. Such knowledge is also important for society to be able to compare benefits and costs (for both animals and other parties) across alternative methods.
Many studies investigating the welfare effects of electric collars on avoidance- or obedience learning in dogs are based on surveys. Scientific studies using objective measures and empirical data are limited.	More knowledge on this topic would gain better insight towards alternative, less aversive training methods.

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